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March 21, 2002

Mr. Stan Komperda
Project Manager
Illinois Environmental Protection Agency
Bureau of Land
1021 North Grand Avenue East
Springfield, Illinois 62794-9276

Re: Groundwater/Enclosed Space Inhalation Risk Evaluation
Lockformer Site, Lisle, Illinois

EPA Region 5 Records Ctr.



265606

Dear Mr. Komperda:

In response to your recent comments, Parsons is pleased to provide the following summary of our evaluation of the inhalation risk posed by groundwater containing dissolved concentrations of trichloroethene (TCE) in the vicinity of the Lockformer site in Lisle, Illinois.

SUMMARY OF ANALYSIS

Parsons performed inhalation risk evaluation using the ASTM 1739-95 Risk-Based Corrective Action standard, Section X2.5, *Ground Water - Inhalation of Enclosed-Space (Indoor) Vapors*. This methodology was used to estimate the inhalation risk in the basement of a theoretical private residence located directly above a groundwater plume of TCE in a subsurface lithology consistent with that of the Lockformer site in Lisle, Illinois. Attachment A includes the relevant pages from the ASTM standard that were used in evaluating this risk. Attachment B contains the specific work sheets developed by Parsons, which include all of the assumed input parameters used in this evaluation and the referenced source for each parameter.

A detailed description of the calculation methodology is included below. In summary, the ASTM analysis indicates that at the maximum concentrations at which TCE has been detected in a private well in the vicinity of the Lockformer site (~20 ppb), the contribution to inhalation cancer risk is less than 1×10^{-6} . Specifically, our analysis was performed using three assumed groundwater concentrations for TCE: 10 parts per billion (ppb), 50 ppb, and 1,000 ppb (or 1 part per million, ppm). The table below shows the resulting inhalation cancer risk posed by each of these assumed concentrations:

TCE Concentration (ug/l)	Inhalation Cancer Risk
10	2.03×10^{-7}
50	1.02×10^{-6}
1,000	2.03×10^{-5}

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IEPA

Environmental Policy & Science



LIMITATIONS OF ANALYTICAL METHODOLOGY

Having supplied the results of our analysis above, we feel it is also important to point out the significant limitations of the analytical method described in the ASTM standard. A quick perusal of the attached worksheets shows the significant number of assumptions that need to be made in order to complete this analysis. The geometry of the lithology, the depth at which the TCE plume is traveling laterally, and the specific geometry of the foundation cracks through which TCE vapors are assumed to enter the indoor space all factor significantly into the results of this analysis; none of these input parameters to the analytical model are known with any degree of certainty for the Lockformer site.

For reasons explained in more detail in the following section, the analysis is particularly sensitive to the thickness of the capillary fringe layer, or in the particular case of the Lockformer site, to the thickness of uncontaminated water that may exist above the horizon at which the TCE plume may be traveling laterally in bedrock. (This sensitivity is related to the fact that any thickness of uncontaminated groundwater will significantly inhibit the diffusion of TCE in an upward direction). An illustration of this model sensitivity is shown in the table below. Three different thicknesses of an uncontaminated, inhibiting groundwater layer were assumed. The corresponding TCE source concentration related to an inhalation risk of 10^{-6} was then calculated. As shown by the table below; the thickness of this groundwater layer is roughly proportional to the source TCE concentration corresponding to a risk level of 10^{-6} .

Assumed Thickness of Inhibiting Groundwater Layer (ft)	TCE Concentration Corresponding to 10^{-6} Inhalation Risk (ug/l)
1	10.6
5	49.2
10	97.5

Because the inhalation risk level varies so significantly with the variation of the inhibiting groundwater layer (an unknown parameter at the Lockformer site), it is important to view the results of our analysis through the context of this limitation. Still, the variation in risk level varies primarily in a conservative manner; i.e., the risk level is likely less than 10^{-6} in the vicinity of the Lockformer site, given all of the currently available information.

DETAILED DISCUSSION OF ANALYSIS

The chemical characteristics of TCE used in the analysis were obtained from Part 742, Illinois Administrative Code. Most of remaining input parameters were obtained directly from the ASTM standard. The inhalation cancer slope factor for TCE was provided by the IEPA.

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The site-specific parameters used in the calculations are depth to groundwater, thickness of the capillary fringe layer, and the thickness of the vadose zone. In our analysis, the air and water volumetric content of the pore space within the capillary fringe layer were modified to reflect the most likely transport mechanisms of the TCE plume at the Lockformer site.

Figure 1 in Attachment A shows modeling assumptions regarding the definition of depth to groundwater, thickness of the capillary fringe, and the thickness of the vadose zone. It is assumed in this model that the constant source of dissolved contamination is already present at the top of the water table and that no diffusion transport is needed for contamination to reach the top of groundwater table from this constant source.

Transport characteristics through soil and the capillary fringe zone depend on the thickness of the zone, the air and water volumetric content of the pore space within the zone, and the compound diffusivity through air and water. The effective diffusion coefficient is a measure for the combined effect of these factors. The air diffusivity coefficient for TCE is several orders of magnitude higher than the corresponding water diffusivity coefficient.

For that reason, the effective diffusion through the capillary fringe zone (containing mostly water) is significantly lower than the effective diffusion coefficient for the vadose zone (containing mostly air). The resulting overall effective diffusion coefficient (calculated for the entire zone over which diffusion takes place) depends most significantly on the thickness of the layer with the smallest diffusion coefficient (the capillary fringe layer). Accordingly, the thickness of this capillary fringe layer is a much more significant input parameter than the thickness of the vadose zone through which the TCE must diffuse.

For the purposes of this analysis, Parsons assumed that the TCE plume has traveled laterally through a network of bedrock fractures to the off-site residential neighborhood, and that at least some of the groundwater in the saturated zone above the bedrock (and beneath the private residences) has not been affected (as would be the case if the release of TCE had originated from directly above). This conclusion has yet to be proven with actual data, but is a reasonable assumption given the likely transport mechanisms of the off-site TCE plume.

The attached evaluation assumes that the constant source of dissolved contamination in bedrock is approximately 5 feet below the groundwater surface. Based on currently available data, this is a conservative assumption (i.e., the thickness of uncontaminated groundwater may be more than 5 feet). Parsons treated this 5-foot layer as a capillary fringe layer by adjusting the volumetric content of soil vapor for this layer to zero to reflect the fact that the entire 5-foot thickness is completely saturated with water.

SUMMARY OF ANALYSIS

Overall, our analysis of the available data using the best available models leads us to conclude that TCE groundwater concentrations above 50 ppb at the Lockformer site could potentially contribute to an inhalation cancer risk greater than 1×10^{-6} ; however, the highest groundwater TCE concentration actually observed in the vicinity of the Lockformer site is less

Mr. Stan Komperda

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than this level (~20 ppb). It should also be noted that the limitations of the calculation methodology should not be ignored; the results of this analysis are very sensitive to changes in input parameters, and our conclusion should only be viewed as a preliminary conclusion based upon the available data. The only way to confidently and quantifiably determine the inhalation risk in the private residences would be through a systematic and empirical air sampling program in the vicinity of the Lockformer site.

We appreciate the opportunity to provide you with this analysis. Please call Mr. Sasa Jazic at any time if you have questions related to this letter, or should require any other additional assistance.

Sincerely,

PARSONS CORPORATION

Sasa Jazic
Project Engineer

Richard M. Frendt, P.E.
Technical Director

SJ/RF:ko
enclosures

cc: Stan Black, IEPA
Maggie Carson, IEPA
Tracy Hurley, IEPA
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File: 739542

ATTACHMENT A
ASTM 1739-95
Ground Water – Inhalation of Enclosed-Space (Indoor) Vapors

tions and parameters used to prepare the example look-up Table X2.1. The basis for each of these equations is discussed in X2.2 through X2.10.

X2.2 Air—Inhalation of Vapors (Outdoors/Indoors)—In this case chemical intake results from the inhalation of vapors. It is assumed that vapor concentrations remain constant over the duration of exposure, and all inhaled chemicals are absorbed. Equations appearing in Tables X2.2 and X2.3 for estimating RBSLs for vapor concentrations in the breathing zone follow guidance given in Ref (26). Should the calculated RBSL exceed the saturated vapor concentration for any individual component, ">P_{sat}" is entered in the table to indicate that the selected risk level or hazard quotient cannot be reached or exceeded for that compound

and the specified exposure scenario.

X2.3 Ground Water—Ingestion of Ground Water—In this case chemical intake results from ingestion of ground water. It is assumed that the dissolved hydrocarbon concentrations remain constant over the duration of exposure. Equations appearing in Tables X2.2 and X2.3 for estimating RBSLs for drinking water concentrations follow guidance given in Ref (26) for ingestion of chemicals in drinking water. Should the calculated RBSL exceed the pure component solubility for any individual component, ">S" is entered in the table to indicate that the selected risk level or hazard quotient cannot be reached or exceeded for that compound and the specified exposure scenario (unless free-phase product is mixed with the ingested water).

TABLE X2.2 Equations Used to Develop Example Tier 1 Risk-Based Screening Level (RBSLs) Appearing in "Look-Up" Table X2.1—Carcinogenic Effects^a

Note—See Tables X2.4 through X2.7 for definition of parameters.

Medium	Exposure Route	Risk-Based Screening Level (RBSL)
Air	Inhalation ^b	$RBSL_{air} \left[\frac{\mu g}{m^3 \cdot air} \right] = \frac{TR \times BW \times AT_e \times 365 \frac{days}{years} \times 10^6 \frac{\mu g}{mg}}{SF_e \times IR_{air} \times EF \times ED}$
Ground water	Ingestion (potable ground water supply only) ^b	$RBSL_{gw} \left[\frac{mg}{L \cdot H_2O} \right] = \frac{TR \times BW \times AT_e \times 365 \frac{days}{years}}{SF_e \times IR_{gw} \times EF \times ED}$
Ground water ^c	enclosed-space (indoor) vapor inhalation ^d	$RBSL_{gw} \left[\frac{mg}{L \cdot H_2O} \right] = \frac{RBSL_{air} \left[\frac{\mu g}{m^3 \cdot air} \right]}{VF_{room}} \times 10^{-3} \frac{mg}{\mu g}$
Ground water ^c	ambient (outdoor) vapor inhalation ^d	$RBSL_{gw} \left[\frac{mg}{L \cdot H_2O} \right] = \frac{RBSL_{air} \left[\frac{\mu g}{m^3 \cdot air} \right]}{VF_{room}} \times 10^{-8} \frac{mg}{\mu g}$
		$RBSL_{soil} \left[\frac{\mu g}{kg \cdot soil} \right] =$
Surface soil	Ingestion of soil, inhalation of vapors and particulates, and dermal contact ^b	$EF \times ED \left[\left(SF_e \times 10^{-6} \frac{kg}{mg} \times (IR_{soil} \times RAF_e + SA \times M \times RAF_d) \right) + (SF_e \times IR_{air} \times (VF_{room} + VF_{soil})) \right]$
		For surficial and excavated soils (0 to 1 m)
Subsurface soil ^c	ambient (outdoor) vapor inhalation ^d	$RBSL_{soil} \left[\frac{mg}{kg \cdot soil} \right] = \frac{RBSL_{air} \left[\frac{\mu g}{m^3 \cdot air} \right]}{VF_{room}} \times 10^{-8} \frac{mg}{\mu g}$
Subsurface soil ^c	enclosed space (indoor) vapor inhalation ^d	$RBSL_{soil} \left[\frac{mg}{kg \cdot soil} \right] = \frac{RBSL_{air} \left[\frac{\mu g}{m^3 \cdot air} \right]}{VF_{room}} \times 10^{-6} \frac{mg}{\mu g}$
Subsurface soil ^c	leaching to ground water ^d	$RBSL_{soil} \left[\frac{mg}{kg \cdot soil} \right] = \frac{RBSL_{gw} \left[\frac{mg}{L \cdot H_2O} \right]}{LF_{gw}}$

^a Note that all RBSL values should be compared with thermodynamic partitioning limits, such as solubility levels, maximum vapor concentrations, and so forth. If a RBSL exceeds the relevant partitioning limit, this is an indication that the selected risk or hazard level will never be reached or exceeded for that chemical and the selected exposure scenario.

^b Screening levels for these media based on other considerations (for example, aesthetic, background levels, environmental resource protection, and so forth) can be derived with these equations by substituting the selected target level for RBSL_{air} or RBSL_{gw} appearing in these equations.

^c These equations are based on Ref (26).

^d These equations simply define the "cross-media partitioning factors," VF_{room} and LF_{gw}.

TABLE X2.4 Exposure Parameters Appearing in Tables X2.2 and X2.3

Parameters	Definitions, Units	Residential	Commercial/Industrial
AT_c	averaging time for carcinogens, years	70 years	70 years ^a
AT_n	averaging time for noncarcinogens, years	30 years	25 years ^a
BW	adult body weight, kg	70 kg	70 kg ^a
ED	exposure duration, years	30 years	25 years ^a
EF	exposure frequency, days/year	350 days/year	250 days/year ^a
IR_{soil}	soil ingestion rate, mg/day	100 mg/day	50 mg/day ^a
IR_{indoor}	daily indoor inhalation rate, m ³ /day	15 m ³ /day	20 m ³ /day ^a
$IR_{outdoor}$	daily outdoor inhalation rate, m ³ /day	20 m ³ /day	20 m ³ /day ^a
IR_w	daily water ingestion rate, L/day	2 L/day	1 L/day ^a
LF_{soil}	leaching factor, (mg/L-H ₂ O)/(mg/kg-soil)—see Table X2.5	chemical-specific	chemical-specific
M	soil to skin adherence factor, mg/cm ²	0.8	0.5 ^a
RAF_d	dermal relative absorption factor, volatiles/PAHs	0.5/0.05	0.5/0.05 ^a
RAF_o	oral relative absorption factor	1.0	1.0
$RBSL_i$	risk-based screening level for media i, mg/kg-soil, mg/L-H ₂ O, or $\mu\text{g}/\text{m}^3\text{-air}$	chemical-, media-, and exposure route-specific	chemical-, media-, and exposure route-specific
RfD_i	inhalation chronic reference dose, mg/kg-day	chemical-specific	chemical-specific
RfD_o	oral chronic reference dose, mg/kg-day	chemical-specific	chemical-specific
SA	skin surface area, cm ² /day	3180	3180 ^a
SF_i	inhalation cancer slope factor, (mg/kg-day) ⁻¹	chemical-specific	chemical-specific
SF_o	oral cancer slope factor, (mg/kg-day) ⁻¹	chemical-specific	chemical-specific
THQ	target hazard quotient for individual constituents, unitless	1.0	1.0
TR	target excess individual lifetime cancer risk, unitless	for example, 10 ⁻⁶ or 10 ⁻⁴	for example, 10 ⁻⁶ or 10 ⁻⁴
VF_i	volatilization factor, (mg/m ³ -air)/(mg/kg-soil) or (mg/m ³ -air)/(mg/L-H ₂ O)—see Table X2.5	chemical- and media-specific	chemical- and media-specific

^a See Ref (27).^a See Ref (28).

surface,

X2.4.2.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.4.2.5 Steady well-mixed atmospheric dispersion of the emanating vapors within the breathing zone as modeled by a "box model" for air dispersion.

X2.4.3 Should the calculated $RBSL_w$ exceed the pure component solubility for any individual component, ">S" is entered in the table to indicate that the selected risk level or hazard quotient cannot be reached or exceeded for that compound and the specified exposure scenario.

X2.5 Ground Water—Inhalation of Enclosed-Space (Indoor) Vapors:

X2.5.1 In this case chemical intake results from the inhalation of vapors in enclosed spaces. The chemical vapors originate from dissolved hydrocarbons in ground water located some distance below ground surface. Here the goal is to determine the dissolved hydrocarbon $RBSL$ that corresponds to the target $RBSL$ for vapors in the breathing zone, as given in Tables X2.2 and X2.3. If the selected target vapor concentration is some value other than the $RBSL$ for inhalation (that is, odor threshold or ecological criterion), this value can be substituted for the $RBSL_{air}$ parameter appearing in the equations given in Tables X2.2 and X2.3.

X2.5.2 A conceptual model for the transport of chemicals from ground water to indoor air is depicted in Fig. X2.2. For simplicity, the relationship between enclosed-space air and dissolved ground water concentrations is represented in Tables X2.2 and X2.3 by the "volatilization factor" VF_{wasp} [(mg/m³-air)/(mg/L-H₂O)] defined in Table X2.5. It is based on the following assumptions:

X2.5.2.1 A constant dissolved chemical concentration in ground water,

X2.5.2.2 Equilibrium partitioning between dissolved chemicals in ground water and chemical vapors at the ground water table,

X2.5.2.3 Steady-state vapor- and liquid-phase diffusion

through the capillary fringe, vadose zone, and foundation cracks,

X2.5.2.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.5.2.5 Steady, well-mixed atmospheric dispersion of the emanating vapors within the enclosed space, where the convective transport into the building through foundation cracks or openings is negligible in comparison with diffusive transport.

X2.5.3 Should the calculated $RBSL_w$ exceed the pure component solubility for any individual component, ">S" is entered in the table to indicate that the selected risk level or hazard quotient cannot be reached or exceeded for that compound and the specified exposure scenario.

X2.6 Surficial Soils—Ingestion, Dermal Contact, and Vapor and Particulate Inhalation:

X2.6.1 In this case it is assumed that chemical intake results from a combination of intake routes, including: ingestion, dermal absorption, and inhalation of both particulates and vapors emanating from surficial soil.

X2.6.2 Equations used to estimate intake resulting from ingestion follow guidance given in Ref (26) for ingestion of chemicals in soil. For this route, it has been assumed that surficial soil chemical concentrations and intake rates remain constant over the exposure duration.

X2.6.3 Equations used to estimate intake resulting from dermal absorption follow guidance given in Ref (26) for dermal contact with chemicals in soil. For this route, it has been assumed that surficial soil chemical concentrations and absorption rates remain constant over the exposure duration.

X2.6.4 Equations used to estimate intake resulting from the inhalation of particulates follow guidance given in Ref (26) for inhalation of airborne chemicals. For this route, it has been assumed that surficial soil chemical concentrations, intake rates, and atmospheric particulate concentrations remain constant over the exposure duration.

X2.6.5 Equations used to estimate intake resulting from

the inhalation of airborne chemicals resulting from the volatilization of chemicals from surficial soils follow guidance given in Ref (26) for inhalation of airborne chemicals.

X2.6.6 A conceptual model for the volatilization of chemicals from surficial soils to outdoor air is depicted in Fig. X2.3. For simplicity, the relationship between outdoor air and surficial soil concentrations is represented in Tables

X2.2 and X2.3 by the "volatilization factor" VF_{ss} $[(\text{mg}/\text{m}^3\text{-air})/(\text{mg}/\text{kg}\text{-soil})]$ defined in Table X2.5. It is based on the following assumptions:

X2.6.6.1 Uniformly distributed chemical throughout the depth $0-d$ (cm) below ground surface,

X2.6.6.2 Linear equilibrium partitioning within the soil matrix between sorbed, dissolved, and vapor phases, where

TABLE X2.5 Volatilization Factors (VF_i), Leaching Factor (LF_{sw}), and Effective Diffusion Coefficients (D_i^{eff})

Symbol	Cross-Media Route (or Definition)	Equation
VF_{wgs}	Ground water \rightarrow enclosed-space vapors	$VF_{wgs} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{L}\text{-H}_2\text{O})} = \frac{H \left[\frac{D_{sw}^{eff}/L_{sw}}{ER L_g} \right]}{1 + \left[\frac{D_{sw}^{eff}/L_{sw}}{ER L_g} \right] + \left[\frac{D_{sw}^{eff}/L_{sw}}{(D_{sw}^{eff}/L_{sw})h} \right]} \times 10^3 \frac{\text{L}}{\text{m}^3} \text{ }^{A, B}$
VF_{wms}	Ground water \rightarrow ambient (outdoor) vapors	$VF_{wms} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{L}\text{-H}_2\text{O})} = \frac{H}{1 + \left[\frac{U_{sw} L_{sw} L_{sw}}{WD_{sw}^{eff}} \right]} \times 10^3 \frac{\text{L}}{\text{m}^3} \text{ }^A$
VF_{ss}	Surficial soils \rightarrow ambient air (vapors)	$VF_{ss} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{2W_{ss}}{U_{ss} L_{ss}} \sqrt{\frac{D_{ss}^{eff} H}{\pi (t_{ss} + k_{ss} \rho_s + H \rho_{ss}) \tau}} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{m}^3\text{-g}} \text{ }^C$ or: $VF_{ss} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{W_{ss} d}{U_{ss} L_{ss} \tau} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{m}^3\text{-g}}; \text{ whichever is less }^D$
VF_p	Surficial soils \rightarrow ambient air (particulates)	$VF_p = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{P_s W}{U_{ss} L_{ss}} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{m}^3\text{-g}} \text{ }^E$
VF_{ms}	Subsurface soils \rightarrow ambient air	$VF_{ms} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{H \rho_s}{(t_{ss} + k_{ss} \rho_s + H \rho_{ss}) \left(1 + \frac{U_{ss} L_{ss} L_{ss}}{D_{ss}^{eff} W} \right)} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{m}^3\text{-g}} \text{ }^F$
VF_{ssw}	Subsurface soil \rightarrow enclosed-space vapors	$VF_{ssw} = \frac{(\text{mg}/\text{m}^3\text{-air})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{H \rho_s}{1 + \left[\frac{D_{ss}^{eff}/L_g}{ER L_g} \right] + \left[\frac{D_{ss}^{eff}/L_g}{(D_{ss}^{eff}/L_g)h} \right]} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{m}^3\text{-g}} \text{ }^A$
LF_{sw}	Subsurface soils \rightarrow ground water	$LF_{sw} = \frac{(\text{mg}/\text{L}\text{-H}_2\text{O})}{(\text{mg}/\text{kg}\text{-soil})} = \frac{\rho_s}{(t_{ss} + k_{ss} \rho_s + H \rho_{ss}) \left(1 + \frac{U_{ss} L_{ss} L_{ss}}{W D_{ss}^{eff}} \right)} \times 10^3 \frac{\text{cm}^3\text{-kg}}{\text{L-g}} \text{ }^G$
D_{ss}^{eff}	Effective diffusion coefficient in soil based on vapor-phase concentration	$D_{ss}^{eff} \left[\frac{\text{cm}^2}{\text{s}} \right] = D_{ss}^{eff} \frac{\rho_{ss} \rho_s}{\rho_s} + D_{ss}^{eff} \frac{1}{H} \frac{\rho_{ss} \rho_s}{\rho_s} \text{ }^{A, B}$
D_{ssw}^{eff}	Effective diffusion coefficient through foundation cracks	$D_{ssw}^{eff} \left[\frac{\text{cm}^2}{\text{s}} \right] = D_{ssw}^{eff} \frac{\rho_{ss} \rho_s}{\rho_s} + D_{ssw}^{eff} \frac{1}{H} \frac{\rho_{ss} \rho_s}{\rho_s} \text{ }^{A, B}$
D_{ssg}^{eff}	Effective diffusion coefficient through capillary fringes	$D_{ssg}^{eff} \left[\frac{\text{cm}^2}{\text{s}} \right] = D_{ssg}^{eff} \frac{\rho_{ss} \rho_s}{\rho_s} + D_{ssg}^{eff} \frac{1}{H} \frac{\rho_{ss} \rho_s}{\rho_s} \text{ }^{A, B}$
D_{ssw}^{eff}	Effective diffusion coefficient between ground water and soil surface	$D_{ssw}^{eff} \left[\frac{\text{cm}^2}{\text{s}} \right] = (H_{sw} + h_w) \left[\frac{h_{sw}}{D_{ssw}^{eff}} + \frac{h_w}{D_{ss}^{eff}} \right]^{-1} \text{ }^A$
C_s^{sat}	Soil concentration at which dissolved pore-water and vapor phases become saturated	$C_s^{sat} \left[\frac{\text{mg}}{\text{kg}\text{-soil}} \right] = \frac{S}{\rho_s} \times (H \rho_{ss} + t_{ss} + k_{ss} \rho_s) \times 10^3 \frac{\text{L-g}}{\text{cm}^3\text{-kg}} \text{ }^F$

^A See Ref (29).

^B See Ref (30).

^C See Ref (31).

^D Based on mass balance.

^E See Ref (32).

^F See Ref (33).

TABLE X2.6 Soil, Building, Surface, and Subsurface Parameters Used in Generating Example Tier 1 RBSLs

NOTE—See X2.10 for justification of parameter selection.

Parameters	Definitions, Units	Residential	Commercial/Industrial
d	lower depth of surficial soil zone, cm	100 cm	100 cm
D_{air}	diffusion coefficient in air, cm^2/s	chemical-specific	chemical-specific
D_{water}	diffusion coefficient in water, cm^2/s	chemical-specific	chemical-specific
ER	enclosed-space air exchange rate, L/s	$0.00014 s^{-1}$	$0.00023 s^{-1}$
f_{oc}	fraction of organic carbon in soil, g-C/g-soil	0.01	0.01
H	henry's law constant, $(cm^3-H_2O)/(cm^3-air)$	chemical-specific	chemical-specific
h_{cap}	thickness of capillary fringe, cm	5 cm	5 cm
h_v	thickness of vadose zone, cm	295 cm	295 cm
I	infiltration rate of water through soil, cm/year	30 cm/year	30 cm/year
k_{oc}	carbon-water sorption coefficient, $cm^3-H_2O/g-C$	chemical-specific	chemical-specific
k_s	soil-water sorption coefficient, $cm^3-H_2O/g-soil$	$f_{oc} \times k_{oc}$	$f_{oc} \times k_{oc}$
L_0	enclosed-space volume/infiltration area ratio, cm	200 cm	300 cm
L_{found}	enclosed-space foundation or wall thickness, cm	15 cm	15 cm
L_{gw}	depth to ground water = $h_{cap} + h_v$, cm	300 cm	300 cm
L_s	depth to subsurface soil sources, cm	100 cm	100 cm
P_0	particulate emission rate, g/cm ² -s	6.9×10^{-14}	6.9×10^{-14}
S	pure component solubility in water, mg/L- H_2O	chemical-specific	chemical-specific
U_{air}	wind speed above ground surface in ambient mixing zone, cm/s	225 cm/s	225 cm/s
U_{gw}	ground water Darcy velocity, cm/year	2500 cm/year	2500 cm/year
W	width of source area parallel to wind, or ground water flow direction, cm	1500 cm	1500 cm
z_{air}	ambient air mixing zone height, cm	200 cm	200 cm
z_{gw}	ground water mixing zone thickness, cm	200 cm	200 cm
γ	areal fraction of cracks in foundations/walls, $cm^2-cracks/cm^2-total\ area$	$0.01\ cm^2-cracks/cm^2-total\ area$	$0.01\ cm^2-cracks/cm^2-total\ area$
θ_{cap}	volumetric air content in capillary fringe soils, cm^3-air/cm^3-soil	$0.038\ cm^3-air/cm^3-soil$	$0.38\ cm^3-air/cm^3-soil$
θ_{found}	volumetric air content in foundation/wall cracks, $cm^3-air/cm^3\ total\ volume$	$0.26\ cm^3-air/cm^3\ total\ volume$	$0.26\ cm^3-air/cm^3\ total\ volume$
θ_v	volumetric air content in vadose zone soils, cm^3-air/cm^3-soil	$0.26\ cm^3-air/cm^3-soil$	$0.26\ cm^3-air/cm^3-soil$
θ_r	total soil porosity, cm^3/cm^3-soil	$0.38\ cm^3/cm^3-soil$	$0.38\ cm^3/cm^3-soil$
$\theta_{cap,w}$	volumetric water content in capillary fringe soils, cm^3-H_2O/cm^3-soil	$0.342\ cm^3-H_2O/cm^3-soil$	$0.342\ cm^3-H_2O/cm^3-soil$
$\theta_{found,w}$	volumetric water content in foundation/wall cracks, $cm^3-H_2O/cm^3\ total\ volume$	$0.12\ cm^3-H_2O/cm^3\ total\ volume$	$0.12\ cm^3-H_2O/cm^3\ total\ volume$
$\theta_{v,w}$	volumetric water content in vadose zone soils, cm^3-H_2O/cm^3-soil	$0.12\ cm^3-H_2O/cm^3-soil$	$0.12\ cm^3-H_2O/cm^3-soil$
ρ_s	soil bulk density, g-soil/cm ³ -soil	1.7 g/cm ³	1.7 g/cm ³
τ	averaging time for vapor flux, s	$7.88 \times 10^4\ s$	$7.88 \times 10^4\ s$

the partitioning is a function of constant chemical- and soil-specific parameters,

X2.6.6.3 Diffusion through the vadose zone,

X2.6.6.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.6.6.5 Steady well-mixed atmospheric dispersion of the emanating vapors within the breathing zone as modeled by a "box model" for air dispersion.

X2.6.7 In the event that the time-averaged flux exceeds that which would occur if all chemical initially present in the surficial soil zone volatilized during the exposure period,

then the volatilization factor is determined from a mass balance assuming that all chemical initially present in the surficial soil zone volatilizes during the exposure period.

X2.7 Subsurface Soils—Inhalation of Outdoor Vapors:

X2.7.1 In this case chemical intake is a result of inhalation of outdoor vapors which originate from hydrocarbons contained in subsurface soils located some distance below ground surface. Here the goal is to determine the RBSL for subsurface soils that corresponds to the target RBSL for outdoor vapors in the breathing zone, as given in X2.2. If the selected target vapor concentration is some value other than

TABLE X2.7 Chemical-Specific Properties Used in the Derivation Example Tier 1 RBSLs

Chemical	CAS Number	M_w , g/mol	H , L- $H_2O/L-air$	D^{air} , cm^2/s	D^{soil} , cm^2/s	$\log(K_{ow})$, L/kg	$\log(K_{oc})$, L/kg
Benzene	71-43-2	78 ^A	0.22 ^A	0.093 ^A	1.1×10^{-4A}	1.5 ^A	2.13 ^A
Toluene	108-88-3	92 ^A	0.28 ^A	0.086 ^A	9.4×10^{-5B}	2.13 ^A	2.85 ^A
Ethyl benzene	100-41-4	106 ^A	0.32 ^A	0.078 ^A	8.5×10^{-5B}	1.98 ^A	3.13 ^A
Mixed xylenes	1330-20-7	106 ^A	0.29 ^A	0.072 ^B	8.5×10^{-5B}	2.38 ^A	3.26 ^A
Naphthalene	91-20-3	128 ^A	0.049 ^A	0.072 ^B	9.4×10^{-6A}	3.11 ^A	3.28 ^A
Benzo(a)pyrene	50-32-8	252 ^C	$5.8 \times 10^{-4}\ ^B$	0.060 ^B	$5.8 \times 10^{-6}\ ^B$	5.59 ^B	5.98 ^B
Chemical	CAS Number	SF_{air} , kg-day/mg	SF_{soil} , kg-day/mg	RfD_{air} , mg/kg-day	RfD_{soil} , mg/kg-day		
Benzene	71-43-2	0.029 ^F	0.029 ^F	...	...
Toluene	108-88-3	...	...	0.2 ^F	0.11 ^F		
Ethyl benzene	100-41-4	...	...	0.1 ^F	0.29 ^F		
Mixed xylenes	1330-20-7	...	...	2.0 ^F	2.0 ^F		
Naphthalene	91-20-3	...	...	0.004 ^G	0.004 ^G		
Benzo(a)pyrene	50-32-8	7.3 ^F	6.1 ^F	...	...

^A See Ref (34).

^B See Ref (36).

^C See Ref (7).

^D Diffusion coefficient calculated using the method of Fuller, Schettler, and Giddings, from Ref (11).

^E Calculated from K_{oc}/K_{ow} correlation: $\log(K_{oc}) = 0.937 \log(K_{ow}) - 0.006$, from Ref (11).

^F See Ref (2).

^G See Ref (3).

the RBSL for inhalation (that is, odor threshold or ecological criterion), this value can be substituted for the $RBSL_{air}$ parameter appearing in the equations given in Tables X2.2 and X2.3.

X2.7.2 A conceptual model for the transport of chemicals from subsurface soils to ambient air is depicted in Fig. X2.4. For simplicity, the relationship between outdoor air and soil concentrations is represented in Tables X2.2 and X2.3 by the "volatilization factor," VF_{soil} [(mg/m³-air)/(kg-soil)], defined in Table X2.5. It is based on the following assumptions:

X2.7.2.1 A constant chemical concentration in subsurface soils,

X2.7.2.2 Linear equilibrium partitioning within the soil matrix between sorbed, dissolved, and vapor phases, where the partitioning is a function of constant chemical- and soil-specific parameters,

X2.7.2.3 Steady-state vapor- and liquid-phase diffusion through the vadose zone to ground surface,

X2.7.2.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.7.2.5 Steady well-mixed atmospheric dispersion of the emanating vapors within the breathing zone as modeled by a "box model" for air dispersion.

X2.7.3 Should the calculated RBSL_{soil} exceed the value for which the equilibrated vapor and dissolved pore-water phases become saturated, C_{sat} [mg/kg-soil] (see Table X2.5 for calculation of this value), "RES" is entered in the table to indicate that the selected risk level or hazard quotient cannot be reached or exceeded for that compound and the specified exposure scenario (even if free-phase product or precipitate is present in the soil).

X2.8 *Subsurface Soils—Inhalation of Enclosed-Space (Indoor) Vapors:*

X2.8.1 In this case chemical intake is a result of inhalation of enclosed-space vapors which originate from hydrocarbons contained in subsurface soils located some distance below ground surface. Here the goal is to determine the RBSL for subsurface soils that corresponds to the target RBSL for indoor vapors, as given in Tables X2.2 and X2.3. If the selected target vapor concentration is some value other than the RBSL for inhalation (that is, odor threshold or

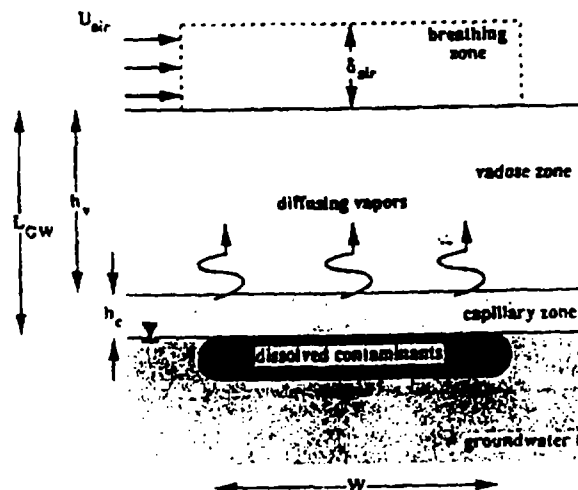


FIG. X2.1 Volatilization from Ground Water to Ambient Air

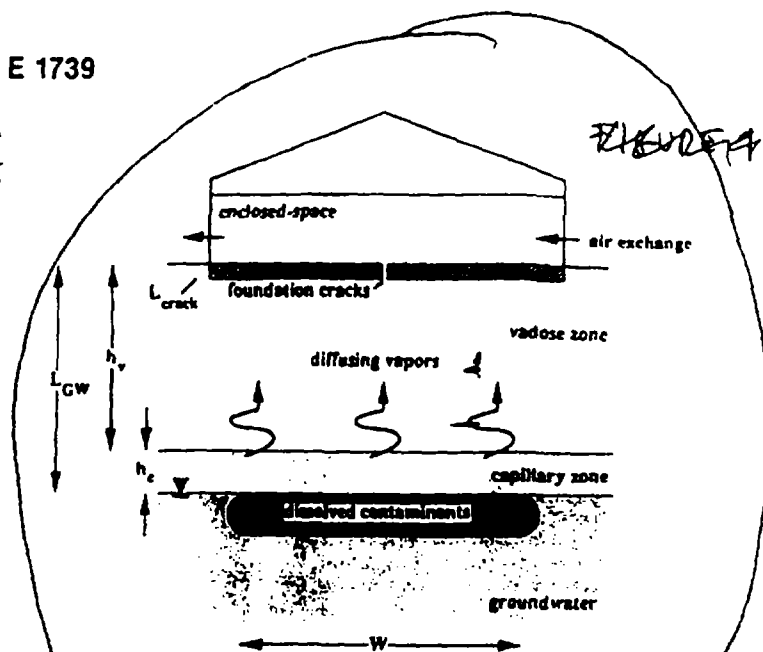


FIG. X2.2 Volatilization from Ground Water to Enclosed-Space Air

ecological criterion), this value can be substituted for the $RBSL_{air}$ parameter appearing in the equations given in Tables X2.2 and X2.3.

X2.8.2 A conceptual model for the transport of chemicals from subsurface soils to enclosed spaces is depicted in Fig. X2.5. For simplicity, the relationship between indoor air and soil concentrations is represented in Tables X2.2 and X2.3 by the "volatilization factor," VF_{soil} [(mg/m³-air)/(kg-soil)], defined in Table X2.5. It is based on the following assumptions:

X2.8.2.1 A constant chemical concentration in subsurface soils,

X2.8.2.2 Linear equilibrium partitioning within the soil matrix between sorbed, dissolved, and vapor phases, where the partitioning is a function of constant chemical- and soil-specific parameters,

X2.8.2.3 Steady-state vapor- and liquid-phase diffusion through the vadose zone and foundation cracks,

X2.8.2.4 No loss of chemical as it diffuses towards ground surface (that is, no biodegradation), and

X2.8.2.5 Well-mixed atmospheric dispersion of the emanating vapors within the enclosed space.

X2.8.3 Should the calculated RBSL_{soil} exceed the value C_{sat} [mg/kg-soil] for which the equilibrated vapor and dissolved pore-water phases become saturated (see Table X2.5 for calculation of this value), "RES" is entered in the table to indicate that the selected risk level or hazard

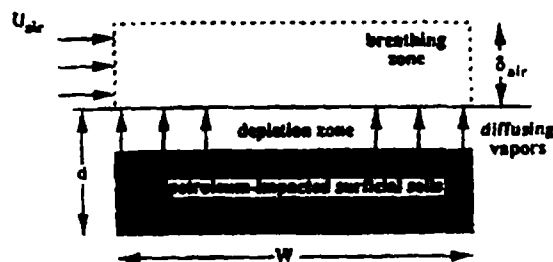


FIG. X2.3 Volatilization from Surficial Soils

ATTACHMENT B
CALCULATION WORKSHEETS

CALCULATION OF SITE-SPECIFIC GROUNDWATER SCREENING LEVEL FOR ENCLOSED-SPACE VAPORS PROTECTION

Private Residence
Vicinity of Lockformer Facility
Lisle, Illinois

Chemical Compound: Trichloroethylene

INPUT PARAMETERS				
Scenario-Specific Parameters				
Parameter	Value	Units	Description	Source
Scenario	Residential	-	Scenario Type	-
TR	1E-06	(unitless)	Target Cancer Risk	ASTM
BW	70	(kg)	Adult Body Weight	ASTM
ATc	70	(years)	Averaging Time for Carcinogens	ASTM
IRair-indoor	15	(m3/d)	Daily Indoor Inhalation Rate	ASTM
EF	360	(d/yr)	Exposure Frequency	ASTM
ED	30	(yr)	Exposure Duration	ASTM
Compound-Specific Parameters				
Parameter	Value	Units	Description	Source
Compound	Trichloroethylene	-	Name of Chemical Compound	-
Sf1	4.00E-01	(mg/kg-d)-1	Inhalation Cancer Slope Factor	IEPA
H	0.42	(unitless)	Henry's Law constant	TACO
Dair	0.079	(cm2/s)	Diffusion Coefficient in Air	TACO
Dwater	9.1E-06	(cm2/s)	Diffusion Coefficient in Water	TACO
Site-Specific Parameters				
Parameter	Value	Units	Description	Source
nf	0.01	(unitless)	Area Fraction of Cracks in Foundations/Walls	ASTM
ER	0.00014	(s-1)	Enclosed-Space Air Exchange Rate	ASTM
Lgw	1826	(cm)	Depth to Groundwater	S
Lb	200	(cm)	Enclosed-Space Volume/Infiltration Area Ratio	ASTM
Lcrack	15	(cm)	Enclosed-Space Foundation or Wall Thickness	ASTM
hcap	182	(cm)	Thickness of Capillary Fringe	S
hw	1373	(cm)	Thickness of Vadose Zone	S
nws	0.12	(unitless)	Volumetric Water Content in Vadose Zone Soils	ASTM
nas	0.26	(unitless)	Volumetric Air Content in Vadose Zone Soils	ASTM
n	0.36	(unitless)	Total Soil Porosity	ASTM
nwcsp	0.36	(unitless)	Volumetric Water Content in Capillary Fringe Soils	S
nacsp	0	(unitless)	Volumetric Air Content in Capillary Fringe Soils	S
nwcrack	0.12	(unitless)	Volumetric Water Content in Foundation/Wall Cracks	ASTM
nacrack	0.26	(unitless)	Volumetric Air Content in Foundation/Wall Cracks	ASTM

S Site Specific Parameter
 ASTM ASTM Standard E 1739-95
 TACO Table E, Default Physical/Chemical Parameters, Part 742, June 1996
 IEPA Value provided by the IEPA
 Eq Value calculated by previous equation

CALCULATION OF SITE-SPECIFIC GROUNDWATER SCREENING LEVEL FOR ENCLOSED-SPACE VAPORS PROTECTION

Private Residence
Vicinity of Lockformer Facility
Lisle, Illinois

Chemical Compound: Trichloroethylene

CALCULATED PARAMETERS				
Effective Diffusion Coefficient in Soil Based on Vapor-Phase Concentration (Ds-eff)				
Input Parameters	Value	Units	Description	Source
Dair	0.079	(cm ² /s)	Diffusion Coefficient in Air	TACO
Dwater	9.10E-08	(cm ² /s)	Diffusion Coefficient in Water	TACO
H	0.422	(unitless)	Henry's Law constant	TACO
nws	0.12	(unitless)	Volumetric Water Content in Vadose Zone Soils	ASTM
nas	0.26	(unitless)	Volumetric Air Content in Vadose Zone Soils	ASTM
n	0.38	(unitless)	Total Soil Porosity	ASTM
Calculated Parameter	Value	Units	Description	Source
Ds-eff	6.14E-03	(cm ² /s)	Effective Diffusion Coefficient in Soil	Eq.
Effective Diffusion Coefficient through Foundation Cracks (Dcrack-eff)				
Input Parameters	Value	Units	Description	Source
Dair	0.079	(cm ² /s)	Diffusion Coefficient in Air	TACO
Dwater	9.10000000E-08	(cm ² /s)	Diffusion Coefficient in Water	TACO
H	0.422	(unitless)	Henry's Law constant	TACO
nwcrack	0.12	(unitless)	Volumetric Water Content in Foundation/Wall Cracks	ASTM
nacrack	0.26	(unitless)	Volumetric Air Content in Foundation/Wall Cracks	ASTM
n	0.38	(unitless)	Total Soil Porosity	ASTM
Calculated Parameter	Value	Units	Description	Source
Dcrack-eff	6.14E-03	(cm ² /s)	Effective Diffusion Coefficient through Foundation Cracks	Eq.
Effective Diffusion Coefficient through Capillary Fringe (Dcap-eff)				
Input Parameters	Value	Units	Description	Source
Dair	0.079	(cm ² /s)	Diffusion Coefficient in Air	TACO
Dwater	9.10E-08	(cm ² /s)	Diffusion Coefficient in Water	TACO
H	0.422	(unitless)	Henry's Law constant	TACO
nwcsp	0.38	(unitless)	Volumetric Water Content in Capillary Fringe Soils	S
nacsp	0	(unitless)	Volumetric Air Content in Capillary Fringe Soils	S
n	0.38	(unitless)	Total Soil Porosity	ASTM
Calculated Parameter	Value	Units	Description	Source
Dcap-eff	6.94E-04	(cm ² /s)	Effective Diffusion Coefficient through Capillary Fringe	Eq.

S Site Specific Parameter
ASTM ASTM Standard E 1739-95
TACO Table E, Default Physical/Chemical Parameters, Part 742, June 1998
IEPA Value provided by the IEPA
Eq Value calculated by previous equation

CALCULATION OF SITE-SPECIFIC GROUNDWATER SCREENING LEVEL FOR ENCLOSED-SPACE VAPORS PROTECTION

Private Residence
Vicinity of Lockformer Facility
Lisle, Illinois

Chemical Compound: Trichloroethylene

CALCULATED PARAMETERS				
Effective Diffusion Coefficient between Groundwater and Soil Surface (Dws-eff)				
Input Parameters	Value	Units	Description	Source
hcap	152.4	(cm)	Thickness of Capillary Fringe	S
hw	1372.6	(cm)	Thickness of Vadose Zone	S
Dcap-eff	5.94E-06	(cm ² /s)	Effective Diffusion Coefficient through Capillary Fringe	Eq.
Ds-eff	6.14E-03	(cm ² /s)	Effective Diffusion Coefficient in Soil	Eq.
Calculated Parameter	Value	Units	Description	Source
Dws-eff	5.89E-06	(cm ² /s)	Effective Diffusion Coefficient between Groundwater and Soil Surface	Eq.
Groundwater - Enclosed Space Vapors Volatilization Factor (VPwesp)				
Input Parameters	Value	Units	Description	Source
H	0.422	(unitless)	Henry's Law constant	TACO
Dws-eff	5.89E-06	(cm ² /s)	Effective Diffusion Coefficient between Groundwater and Soil Surface	Eq.
Lgw	1525	(cm)	Depth to Groundwater	S
ER	0.00014	(s ⁻¹)	Enclosed-Space Air Exchange Rate	ASTM
Lb	200	(cm)	Enclosed-Space Volume/Infiltration Area Ratio	ASTM
Dcrack-eff	6.14E-03	(cm ² /s)	Effective Diffusion Coefficient through Foundation Cracks	Eq.
Lcrack	15	(cm)	Enclosed-Space Foundation or Wall Thickness	ASTM
ni	0.01	(unitless)	Area Fraction of Cracks in Foundations/Walls	ASTM
Calculated Parameter	Value	Units	Description	Source
VPwesp	6.77E-04	(mg/m ³)/(mg/L)	Groundwater - Enclosed Space Vapors Volatilization Factor	Eq.
Risk-Based Screening Level for Inhalation (RBSLair)				
Input Parameters	Value	Units	Description	Source
TR	1E-06	(unitless)	Target Cancer Risk	ASTM
BW	70	(kg)	Adult Body Weight	ASTM
ATc	70	(years)	Averaging Time for Carcinogens	ASTM
IRair-indoor	15	(m ³ /d)	Daily Indoor Inhalation Rate	ASTM
EF	360	(d/yr)	Exposure Frequency	ASTM
ED	30	(yr)	Exposure Duration	ASTM
SFI	0.4	(mg/kg-d) ⁻¹	Inhalation Cancer Slope Factor	IEPA
Calculated Parameter	Value	Units	Description	Source
RBSLair	2.84E-02	(ug/m ³)	Risk-Based Screening Level for Inhalation	Eq.

S Site Specific Parameter
ASTM ASTM Standard E 1739-95
TACO Table E, Default Physical/Chemical Parameters, Part 742, June 1998
IEPA Value provided by the IEPA
Eq Value calculated by previous equation

CALCULATION OF SITE-SPECIFIC GROUNDWATER SCREENING LEVEL FOR ENCLOSED-SPACE VAPORS PROTECTION

Private Residence
Vicinity of Lockformer Facility
Lisle, Illinois

Chemical Compound: Trichloroethylene

CALCULATED PARAMETERS				
Risk-Based Screening Level for Enclosed-Space Vapor Inhalation (RBSLw)				
Input Parameters	Value	Units	Description	Source
RBSL _{air}	2.84E-02	(ug/m3)	Risk-Based Screening Level for Inhalation	Eq.
VF _{wesp}	5.77E-04	(mg/m3)/(mg/L)	Groundwater - Enclosed Space Vapors Volatilization Factor	Eq.
Calculated Parameter	Value	Units	Description	Source
RBSL _w	4.82E-02	(mg/L)	Risk-Based Screening Level for Enclosed-Space Vapor Inhalation	Eq.

S	Site Specific Parameter
ASTM	ASTM Standard E 1739-95
TACO	Table E, Default Physical/Chemical Parameters, Part 742, June 1996
IEPA	Value provided by the IEPA
Eq	Value calculated by previous equation